International Journal of Gerontology 8 (2014) 213–218

Contents lists available at ScienceDirect

International Journal of Gerontology

journal homepage: www.ijge-online.com

Original Article

Efficacy of Progressive Resistance Tube Training in Community Dwelling Older Adults: A Pilot Study

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A R T I C L E I N F O

Article history:
Received 16 May 2013
Received in revised form
2 August 2013
Accepted 3 December 2013
Available online 2 December 2014

Keywords:
aged,
muscle strength,
postural balance,
resistance training

S U M M A R Y

Background/objective: Falls are known to be one of the most prevalent public health problems in older adults. Currently, the aging population is growing fast. It is essential to use low cost, time-efficient exercise intervention programs for increasing strength, functional mobility, and balance in older adults, and subsequently decrease the risk of falls. This is a pilot study to assess the effects of a 12-week progressive resistance tube training session on the lower limb muscle strength, dynamic balance, and functional mobility in elderly people.

Methods: Seventeen community dwelling older adults with a mean age of 69.2 ± 4.62 years were recruited among residents of a senior day care center in Malaysia to participate in this pilot study. Eight out of 17 participants completed their lower extremity resistance tube training sessions three times per week for 12 weeks. Lower limb muscle strength and functional mobility were tested by five times sit to stand test (FRSTST), and timed up and go test (TUG), respectively. Functional reach test (FRT) and four square step test (FSST) were applied to measure dynamic balance.

Results: The results revealed significant increases in lower limb strength (30.3%), dynamic balance (29.6% in FRT and 15.3% in FSST), and functional mobility (27.1%) (all significant at $p < 0.05$).

Conclusion: It was concluded that the use of a simple and inexpensive strength training program may improve leg muscle strength and consequently dynamic balance and mobility in elderly people and make them independent in their daily activities.

1. Introduction

Falls are common and potentially fatal events causing functional, psychological, and also social problems in elderly people[1,2]. Annually, nearly 30% of people over the age of 65 years have experienced a fall[3], in which one out of three are hospitalized as a result of fall related injuries[4]. The injuries vary from slight bruising to fracture, coma, and even death[5] and lead to less independence[6]. Impairments in balance, gait, and lower limb strength are important factors that increase fall rates and inactivity[7] which might impact on the quality of life for elderly people[8].

Muscle strength reduces nearly 15% after the age of 50 years and by twofolds after the age 70 years per every decade[9]. It is believed that both muscle mass atrophy and muscle fiber reduction are effective factors in this process. Fortunately, it is potentially preventable and reversible with proper nutritional interventions and exercise involvement[10]. Strength training has been shown to prevent and improve the reduction of muscle strength, mass, and functional capacity[11,12] and falls in older adults[13,14]. In spite of these benefits, there are only a few safe and efficient progressive resistance training programs accessible and affordable for older adults[15]. Most resistance training is performed in a clinical laboratory using weight machines[14]. However, elderly people have difficulties in traveling to sport locations, and therefore do not achieve enough exercise[13]. To impart the benefits of resistance training exercise, development of inexpensive and practical alternative instruments are required[16].

Elastic bands or tubes are easily available, inexpensive, and easy to carry, and older adults can use this equipment to perform and maintain the exercise programs long-term almost everywhere[13,17]. Hence, the objectives of this study were to assess the effects of a cost effective and accessible resistance training program on lower extremity muscle strength, balance, and functional mobility in

Conflicts of interest: All contributing authors declare that they have no conflicts of interest.

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http://dx.doi.org/10.1016/j.ijge.2013.12.007
1873-9598/

elderly people using elastic tubes. The provision of low-cost exercise programs would help to decrease frailty and improve independent lifestyle in older adults.

2. Materials and methods

The study was approved by the Medical Research Ethics Committee of the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Selangor, Malaysia {UPM/FPSK/100-9/2-MJKEtikaPen [IG_Jun (12) 05]} which were in agreement with the Declaration of Helsinki on ethical principles for medical research involving humans.

This pilot study applied single-group, pretest–posttest design to assess the intervention effect. We selected this design with regard to some rational reasons. This design has natural limitations regarding the power and also generalizability of the outcomes, consequence of small sample size as well as lack of a control group. However, a pilot study provides a way to explore sample recruitment, intervention design, and methodological issues which enable it to indicate whether further investigation is necessary. Conducting a pilot study assists with developing, modifying, or confirming the feasibility of techniques and also estimate what the final sample size should be.

2.1. Sample

The potential participants aged $\geq$ 60 years were recruited from an elderly day center under the Central Welfare Council of the Federal Territory of Kuala Lumpur to participate in the pilot study. The process of the study is shown in the flowchart (Fig. 1). Potential participants were interviewed to obtain demographic data, health history, physical activity, fall history, and mental status based on individual structured questionnaires. All participants completed and signed the consent form after being informed on the nature, the potential risks of the study provided by the researcher, and the information sheet. They were assessed by a physician for medical clearance prior to taking part in the study. Inclusion criteria consisted of independence in daily living activity, not recent (past 3 months) participation in regular lower body resistance training (at least twice per week), ability to understand the study protocols and follow the instructions. Recruited persons were excluded if they had an allergy to the natural rubber latex in the resistance tube; recent myocardial infarction; uncontrolled hypertension; Parkinson's disease; diagnosed vestibular disorders; severe knee and back pain, knee joint replacement, rheumatoid arthritis, lower limb surgery in the past 6 months, Multiple sclerosis, known diabetic neuropathy, diagnosed osteoporosis; stroke within the past year; diagnosed stage three and four of heart failure in accordance with the New York Heart Association functional classification system; and any medical problems that would prohibit safety involved in moderate intensity progressive resistance training. The seniors who take regular medications impairing balance ability (sedatives, antidepressants, neuroleptics, or benzodiazepines) or muscle strength (corticosteroids) were excluded from this study.

2.2. Exercise program

Prior to the exercise program, participants attended a training class on how to use the elastic tube. They were also given an exercise book (consisting of pictorial elastic tube training guidelines).

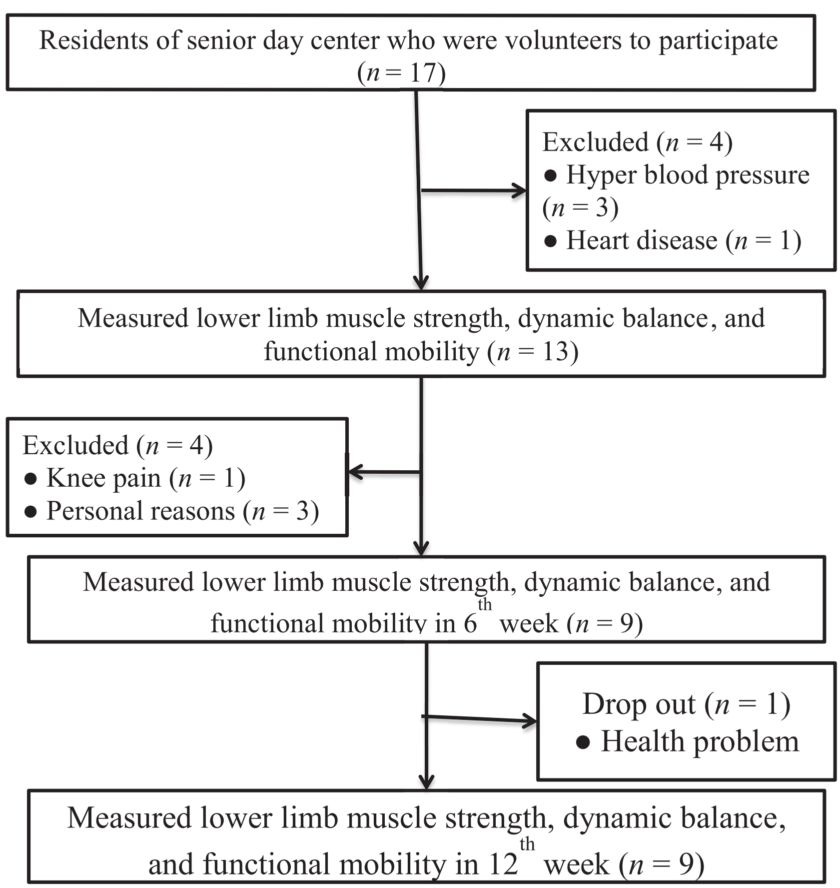

Fig. 1. Procedure of selecting participants, intervention, and outcomes by flowchart.

The exercise sessions were carried out three times per week (twice in the senior day center and once at home) over 12 weeks. Each exercise session took a maximum of 60 minutes with 5 minutes warming up, 50 minutes strength training by elastic tube, and 5 minutes cooling down. At the center, the participants performed the exercise in a group basis and were supervised for proper performance and safety during the session by a qualified exercise trainer.

In the current study, the exercise session exceeded the recommended guidelines by the American College of Sports Medicine for resistance training in older adults because the participants needed some additional time to be helped in staying in the correct position. The researchers also spent some more time repeating the instruction for proper performance by the participants. They did not feel fatigued during the exercise sessions as they got enough rest between sets and exercises, and they were trained in low and moderate intensity and were supported by holding a door, wall, or chair.

The training procedure consisted of concentric and eccentric dynamic progressive resistance training. High intensity exercises in older adults significantly increase heart and respiratory rate[18]. Therefore, the exercises were conducted at moderate intensity as estimated by the Borg scale used for rating perceived exertion[19]. The Borg rating of perceived exertion (RPE) scale was established to allow simple, reliable, and valid assessments of exercise intensity[20]. This scale is known as a valid rating instrument to evaluate perceived exertion and also identify the intensity used throughout resistance exercise[21,22]. It has been shown that the Borg RPE scale is associated with certain physiological indices of resistance exercise intensity. These physiological measures are blood lactic acid concentration[23,24] and muscle activity[25,26] that mediate the intensity of exertion perceptions. Lagally et al[25] demonstrated the concurrency of the Borg RPE scale during resistance exercise using the percentage of 1 repetition maximum (1RM) elevated as criterion variables.

The intervention involved multi-joint targeted major lower extremity muscle groups. Participants were encouraged to pull on the tubes through concentric phase (2 seconds), and then return slowly to the first position during the eccentric phase (4 seconds) for each exercise. They rested for 2–3 seconds between repetitions and for 1 minute between sets, and 2–3 minutes between different exercises. Multiple-joint exercises were performed prior to single-joint exercises. The exercises were performed in the order: chair squat, leg press, hip flexion and extension, hip abductions and adductions, knee flexion, leg extension, plantar flexion, dorsi-flexion, and calf raise. The exercises were conducted first by low intensity, one set within the 1st week, progressing to two sets in the 2nd week and three sets in the 3rd week, all with 8–10 repetitions. Individuals gradually increased tube resistance allowing sufficient connective tissue adaptation. Once the participants could easily perform three sets with 10 repetitions for a given elastic tube, the resistance of the tube was changed to a stronger one[27].

The blood pressure and heart rate were assessed prior to and after each exercise session continuously. For safety reasons, when a participant's blood pressure was over either 170 mmHg systolic or 100 mmHg diastolic and heart rate > 60% of maximum heart rate (220 beats/min minus the participant's age), the person was prohibited from exercising that session. This never occurred for any participant during the training sessions. The mean blood pressure and heart rate changed little (systolic blood pressure < 10 mmHg and heart rate < 7 beats/min) throughout the exercise sessions.

2.3. Measurement

The variables that were assessed in the present study included lower limb muscle strength, dynamic balance, and functional mobility. For all measurement tests, participants performed one practice for familiarization and then completed two trials. The average score of the two trials was used in the analysis.

The 5-repetition sit-to-stand test (FRSTST) was used to measure the lower extremity muscle strength[15,28]. In this test, participants sat on a standard armless chair with height of 43 cm from the floor. They were requested to stand up and sit down five times, as fast as possible, while keeping the arms across the chest. The time from the first to the last seated position after finishing a five-time stand was recorded with a stop-watch.

The functional reach test (FRT) was used to measure dynamic balance. This test is recommended for elderly people[5,29]. Functional reach test is the maximal distance that a person can lean forward in the standing position. In FRT, the participant is asked to stay close to the wall with feet together, fist-off the hand, and reach forward as far as possible through a yardstick which is fixed on to the wall and hold for three seconds. The distance was recorded in centimeters from the first upright position for maximal reaching forward with heels placed in contact with the floor. In older adults, the FRT scores lower than 15 cm show a considerable risk of falling[29].

The four square step test (FSST) was used to assess the dynamic balance, or the capability of stepping over short height objects (2.5 cm) and changing the movement in four directions. To perform this test, four canes were placed on the ground to make the four squares. The participant stands up in Square 1 in front of Square 2 and moves clockwise from Square 1 to Squares 2–3–4 and Square 1 again and returns from Squares 1–4–3–2–1. Time was recorded from the time the first foot was put in Square 2 until both feet are in contact with the floor when back to Square 1. The participants were asked to perform the sequence as quickly as possible without hitting the canes; with both feet touching the ground in each square, and attempt to face forward throughout the whole sequence. The participants with FSST scores of > 15seconds are at risk of falling[19,30].

The timed up and go test (TUG) was used to measure functional mobility. The participants sat on a standard height chair (45 cm) with their back touching the chair cushion. They were asked to rise from the chair, walk 3 m towards the wall as fast as possible, turn around and sit down with their back against the chair again. The TUG score was measured from the first to the end seated position and a similar chair was used at baseline and for each record.

2.4. Data collection

All measurements were conducted three times: once prior to and twice after intervention at the 6th week and 12th week of the study.

2.5. Data analysis

The statistical analysis was carried out using SPSS version 19 (SPSS IBM, New York, NY, USA) for Windows at 95% power analysis. The results were reported for baseline and postintervention. The proportion of improvements from pre- to postintervention was calculated for all the tests based on differences in the means. The data were subjected to one way repeated measure analysis of variance followed by pairwise comparisons to assess the main effects (among three trials) on lower muscle strength, balance, and functional mobility. The normal distribution of data was detected using Kolmogrov and Shapiro-Wilk tests. A p value < 0.05 was taken to be significant.

Table 1
Demographic characteristics of study population.

Characteristics	*N* (%)	Mean (SD)
Age (y)	8	69.2 (4.62)
Gender		
Female	4 (50.0)	
Male	4 (50.0)	
Ethnicity		
Malay	3 (37.5)	
Chinese	5 (62.5)	
Marital Status		
Married	5 (62.5)	
Widowed	3 (37.5)	
Education		
No formal education	1 (12.5)	
Primary school	4 (50.0)	
Secondary school	3 (37.5)	
Employment		
Retired	6 (75.0)	
Housewife	2 (25.0)	

3. Results

Four out of 17 recruited individuals did not meet the inclusion criteria. In addition, another four individuals were excluded after baseline measurements due to personal reasons. Compliance to follow the exercise program was good and just one participant dropped out for health reasons (cancer diagnosis) after starting the intervention. The demographic characteristics of the study population are presented in Table 1.

Table 2 presents the mean and the percentage of change in leg muscle strength, dynamic balance, and functional mobility measurements after 6 weeks and 12 weeks of the intervention program. The results indicated a significant improvement in clinical tests after the intervention period ($p < 0.05$). After the 12-week resistance training, 30.3% and 27.1% improvement were observed in lower limb strength and functional mobility, respectively. A corresponding improvement of 15.3% and 29.6 % were recorded for FRT and FSST, respectively.

Fig. 2 illustrates the box-plots of lower extremity muscle strength, dynamic balance, and functional mobility for the three measurements and the respective trends.

4. Discussion

The results of this study showed ~30% gain in lower extremity muscle strength after 12 weeks of resistance tube training program. However, some earlier studies found better improvement in muscle strength compared with the present study. This inconsistency may be attributed to the sample source, duration of the exercise program, and the intensity of resistance band training used. For example, the members of a nursing home with poor muscle strength were trained and had been shown to gain > 50% of muscle

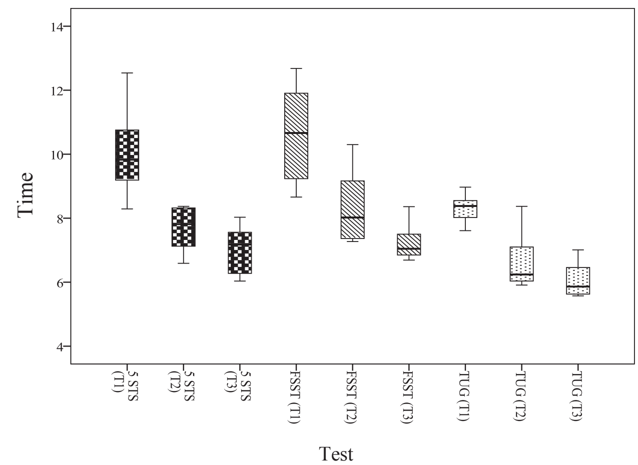

Fig. 2. Box-plot of lower extremity muscle strength, dynamic balance, and functional mobility measured by five times sit to stand test (STS), four square step test (FSST), and timed up and go test (TUG) respectively in prior to training and the 6th week and 12th week of training. Key: a box represents the interquartile range; a line across the box indicates the median; bars (whiskers) extend from the box to the highest and lowest values. FSST = four square step test; STS = sit-to-stand test; T = trial; TUG = time up and go test.

strength[7,11]. Some studies used long training durations (1–2 years) and reported high improvements in muscle strength[14,31]. Hess and Woollacott[32] stated that a great improvement in muscle strength (42–52%) may be related to high intensity strength training.

The findings of the present study demonstrated a large improvement in dynamic balance (15.27% in FRT and 29.6% in FSST) and functional mobility (27.1% in TUG). Improvement in balance performance may be due to an increase in type II versus type I muscle fibers with a larger cross-sectional region and improvement in torque enlargement[33]. In addition, leg muscle strength is a contributing factor for balance-demanding tasks in daily routines such as chair rising, walking, turning, and stair climbing[34]. Lower body muscle impairment has been distinguished as an effective risk factor relating to poor balance and falls in older adults[35]. It has been shown that lower muscle strength, mainly of the ankle muscle, is an important factor in balance performance[36]. Hence, in the present study the interventions involved major muscle groups of the lower extremities (ankle, hip, and knee), which are essential parameters for balanced performance.

The range of improvements in leg muscle strength, balance, and functional mobility were in good agreement. In particular, the balance and functional mobility increased with the gain in lower body muscle strength.

Although the results may differ in some published studies[37,38], they are consistent with other reported results[7,39] which found a significant influence of resistance training on dynamic balance performance. The discrepancies may be due to different methods

Table 2
Percentage change in muscle strength (STS 5), balance (FRT and FSST), and functional mobility (TUG) prior to training, on the 6th week, and 12th week after training.

Test	T1 M ± SD	T2 m ± SD	T3 m ± SD	% changes		
				T1T2	T2T3	T1T3
STS5	10.1 ± 1.3	7.7 ± 0.7	7.0 ± 0.7	−23.6**	−8.7*	−30.3**
TUG	8.3 ± 0.5	6.6 ± 0.9	6.1 ± 0.6	−20.2*	−8.6*	−27.1**
FRT	27.3 ± 3.0	30.1 ± 2.9	31.5 ± 3.5	10.3**	4.5*	15.3**
FSST	10.6 ± 1.5	8.3 ± 1.2	7.2 ± 0.6	−21.5*	−13.3*	−29.6**

*$p < 0.05$.
**$p < 0.001$.
FRT = functional reach test; FSST = four square step test; STS5 = five times sit to stand test; T = trial; T1 = baseline; T2 = 6th week; T3 = 12th week; TUG = time up and go test.

used in the strength training program. Some studies did not target the key muscles for balanced performance. Hence, the results showed no significant improvement in balance ability[37].

On the effect of PRT on functional mobility, the present findings are in agreement with several previous reports[7,11,17,39]. However, there were some differences in the quantity of improvement achieved. For example, Rogers et al[17] showed a 9.8% decrease in TUG time after 4 weeks of exercise, whereas Ribeiro et al[7] found a 40% reduction after 6 weeks of progressive elastic band training. It is therefore important to consider the range of baseline measurements of TUG that may be considerably different. The baseline of TUG varied from 8.2 seconds[17] to 18.2 seconds[7]. On top of that, the amount of functional mobility improvement was highly related to the range of leg muscle strength and balance improvement[40]. Therefore, it is likely that the large improvement in the leg muscle strength in the present study effectively increased the functional mobility of the seniors.

It is interesting to note that all eight cases in this study were enthusiastic on both progressive resistance tube training program and the efficient gain in strength, balance, and mobility improvement.

4.1. Clinical implications

The findings of the present study provide support for using inexpensive training equipment by community dwelling older adults or institutionalized seniors. The use of effective and low cost exercise training that improves functional mobility is an essential indicator of the health status of older adults. Furthermore, it makes them more independent and decreases the strain on the family and the health care center. It is important to introduce and assess proper training programs to the practitioners before a health care disaster happens. The use of elastic bands or tubes in preference to weight machines provide an opportunity to maintain the exercise program among elderly people for a long time.

4.2. Limitations

The small sample size and lack of a control group limit the generalizability of the study. However, as this was a pilot study to collect preliminary data, the single group design was considered as an appropriate option.

5. Conclusion

The evidence from this study suggests that large strength gains that result in enhancement in balance performance and mobility can be achieved using simple effective and inexpensive equipment. A larger randomized controlled trial would certainly provide more definitive evidence. In general however, it seems that use of this low cost training program among community dwelling seniors and older adults will make them more independent in their daily activities.

Acknowledgments

The study was supported by Grant No. 9365500 from the Institute of Gerontology, Universiti Putra Malaysia (UPM). We wish to thank all the staff of the Institute of Gerontology, Universiti Putra Malaysia, Dr.Noraliza, and the authorities in charge of the daycenter as well as its residents for their immense contributions towards this study. In addition, our thanks go to Dr. Hamid R. Naji for his assistance and helpful comments during the study.

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